CHAPTER 3 RESULTS

3.1 LIST OF EXPOSURE-RELEVANT TASKS

The list of 32 exposure-relevant tasks (plus other) forms the basis of this task-exposure

approach to epidemiologic exposure assessment. These tasks, with their descriptions, are

as follows:

1. **Electrical utility work, three phase:** Involves electrical work on or within 1 meter of a three-phase energized source.

2. **Electrical utility work, single phase:** Involves electrical work on or within 1 meter of a single-phase energized source.

3. **Electrical utility work, nonenergized:** Involves electrical work on or within 1 meter of a non-energized source.

4. **Electrical utility work, substation:** Involves electrical work inside or within 1 meter of a substation.

5. **Electrical and electronic equipment assembly, testing, and repair:** Testing, repairing, and assembling electronic equipment using various types of diagnostic equipment. Includes equipment such as logic testers, oscilloscopes, ammeters, multimeters, etc.

6. **Computer data entry or retrieval:** Involves using a computer to enter or retrieve information. Also includes related equipment such as computer scanners, printers, external disk drives, etc.

7. **Using an office/business machine:** Operating equipment found in an office or business environment. Includes machines such as faxes, copiers, typewriters, electric staplers, audiovisual equipment (overhead projectors), etc. Does not include computers.

8. **Operating or riding in a gas/diesel motor vehicle:** Involves operating or riding in a vehicle that primarily runs on streets and highways. Includes vehicles such as cars, trucks, vans, buses, and tractor trailers.

9. **Operating or riding in an industrial vehicle:** Involves operating vehicles that are used in industrial operations. These vehicles generally don't operate on streets and highways. Includes vehicles such as forklifts, tractors, bulldozers, cranes, etc.

10. **Operating a ship, airplane, train, trolley:** Involves operating or riding in any type of ship, airplane, train, or trolley.

11. **Monitoring in a control room or dispatch center:** Involves working in a control room that may contain computer monitors, gauges, dials, etc. Includes operating a power plant, dispatching work, monitoring security systems, air traffic control, etc.

12. **Operating/tending industrial machinery:** Operating miscellaneous types of fixed placement machinery typically found in production or construction settings such as boilers, turbines, compressors, presses, mixers, textile machines, etc.

13. **Repairing/maintaining industrial machinery:** Repairing and maintaining fixed placement machinery such as boilers, turbines, compressors, presses, mixers, textile machines, etc.

14. **Operating electric power tools:** Involves operating electric motorized tools. Includes equipment such as sanders, grinders, drills, saws, etc.

15. **Operating non-electric power tools:** Involves operating pneumatic (air) or hydraulic powered tools.

16. **Installing/maintaining telecommunications networks:** Installing equipment for various types of telecommunication systems such as wireless communication, cable television, telephone wiring, PBX equipment, satellite communications, etc.

17. **Using telecommunications equipment/devices:** Using equipment, often hand-held, but sometimes desktop that aids in wireless and other types of communication. Includes equipment such as telephones, cellular phones, CB radios, walkie-talkies, intercoms, phone switchboards, etc.

18. **Operating biomedical/analytical equipment:** Operating various equipment typically found in the medical/scientific research fields. Includes items found in a hospital, doctor's office, or research laboratory. May include microscopes, incubators, centrifuges, gas chromatographs, etc.

19. **Operating/tending an electric furnace or heating device:** Operating or tending electric powered devices that generate heat such as an electric kiln, furnace or smelter, RF seam sealer, electric heat sealer, etc.

20. **Operating magnetic-based equipment:** Operating equipment that contains a large magnet such as a book deactivator in a library, deactivators/degaussers, machines that use nuclear magnetic resonance technology, metal detector, etc.

21. **Welding/metal working:** Using equipment to manipulate metal while doing activities such as welding, cutting, or brazing.

22. **Operating x-ray equipment:** Operating equipment that uses x-rays to carry out its primary functions. Includes x-ray machines, x-ray crystalography.

23. **Cleaning/janitorial work:** Cleaning and maintaining commercial and private buildings. May do activities such as sweeping, dusting, an vacuuming. Often involves use of vacuums, buffers, polishers, irons, etc.

24. **Cooking/food preparation:** Preparing food for immediate eating or distribution using equipment typically found in a kitchen or food production setting.

25. **Freight handling/warehouse work:** Involves moving material from one destination to another using equipment such as hand carts, conveyor belts, or lifting devices. Bar-code scanners may be used for inventory purposes. Forklift use is classified as operating an industrial vehicle.

26. **Groundskeeping:** Working with plants, soil, other materials, and various tools to do landscape work, gardening, cultivation, tree trimming, etc. Gasoline powered equipment such as lawn mowers, leaf blowers, and chain saws may be used.

27. **Personal services:** Providing services such as hair cutting, blow drying, shaving, maricures, massages, electrolysis, etc.

28. **Production/assembly work:** Involves taking provided parts to create or insert subunits into a final product. Includes packaging.

29. **Retail check-out:** Involves taking payment in exchange for goods and services, using equipment such a cash registers, bar-code scanners, electronic scales, adding machines, credit card machines, etc.

30. **Survey/inspection/delivery work:** Includes traveling to other locations to obtain or deliver information. Also includes monitoring/patrolling, meter reading, mail delivery, messenger services, building inspections/appraising.

31. **Meeting:** Includes being involved in a meeting, conference, seminar, training session, or pre/post shift debriefing.

32. **Lunch/break:** Lunch or other break.

33. **Other:** Any other work-related tasks not specified in other categories.

3.2 TASK-BASED TIME LOG QUESTIONNAIRE

The task-based time log questionnaire that was developed based on this approach was tailored to the utility workers in the Colorado State University study population (see section 2.3). As a result, only a subset of the 32 tasks in the list appear on this instrument, which is shown below in Figure 3-1 (front and back). In addition, for CSU evaluation study, the task category of electrical utility work was separated into four tasks as it was on the task list.

Figure 3-1. Task-based time log questionnaire, front (back on next page).
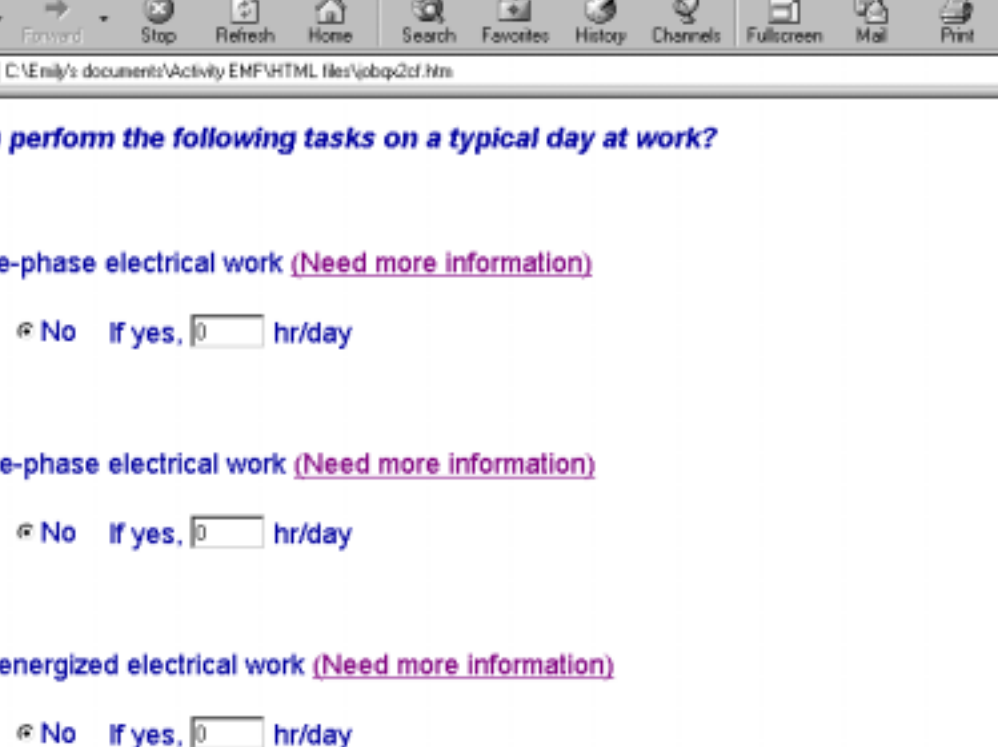
DAY TWO TUESDAY Date _____ Subject ID _____

TIME	Electrical work					Office work		Vehicle operation		Equipment operation and maintenance										Other activities					
	Three Phase linework	Single Phase line work	Nonenergized linework	Substation	Electrical and electronic equipment assembly, testing, and repair *test instruments, meters*	Computer data entry or retrieval *computers and related accessories such as scanners*	Office/business machine *fax, copiers, typewriters, overhead projectors, audiovisual equipment*	Gas/diesel motor vehicle *cars, trucks, vans, buses, tractor trailers, includes passengers*	Industrial vehicle *forklifts, tractors, bulldozers, cranes*	Monitoring in a control room or dispatch center *power plant operator, dispatcher, security systems*	Monitoring industrial machinery *fixed machinery such as boilers, turbines, compressors, presses, mixers*	Repairing and maintaining industrial machinery *boilers, turbines, etc.*	Electric power tools *hand-held electric motorized tools such as drills, saws, sanders, grinders*	Non-electric power tools *air or hydraulic powered*	Installing/maintaining telecommunications networks *telephone, cable, cellular, PBX, satellite*	Using telecommunications equipment devices *telephones, cell phones, CBs, 2-way radios, switchboards*	Magnetic-based equipment *demagnetizer, metal detector, book deactivator, NMR*	Welding/metal working *welding, cutting, brazing*	Cleaning/janitorial work *vacuuming, sweeping, dusting, polishing, buffing*	Freight handling/warehouse work *conveyor belts, lifting devices, hand carts, inventory scanners*	Groundskeeping *tree trimming, landscape work, gardening, using lawn mowers, leaf blowers, chain saws*	Survey/inspection/delivery work *meter reading, parts delivery, building inspection, patrol*	Meeting *training, shift debriefing, conference*	Lunch/break
6:00																								
7:00																								
8:00																								
9:00																								
10:00																								
11:00																								
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INSTRUCTIONS: Mark an X in the box for the time that you did a specific task. Draw a line down to indicate if you did it for more than one time period in a row.
Record tasks that you do for one half hour or more. For half hours please split the box and indicate which half hour the task was done.
If you do more than one activity at a time, mark the box for each activity.
For "Other" activities, write in the activity in the box for the corresponding time.

Figure 3-1, continued. Task-based time log questionnaire, back.

Electrical work	Operating or riding in an industrial vehicle	Operating non-electric power tools	Cleaning/janitorial work
Includes utility linework (three phase, single phase, nonenergized). Also includes commercial and residential electrical work.	Involves operating vehicles that are used in industrial operations. These vehicles generally don't operate on streets and highways, includes vehicles such as forklifts, tractors, bulldozers, cranes, etc.	Involves operating pneumatic (air) or hydraulic powered tools.	Cleaning and maintaining commercial and private buildings. May do activities such as sweeping, dusting, and vacuuming. Often involves use of vacuums, buffers, polishers, irons, etc.
Electrical and electronic equipment assembly, testing, and repair	**Monitoring in a control room or dispatch center**	**Installing/maintaining telecommunications networks**	**Freight handling/warehouse work**
Testing, repairing, and assembling electronic equipment using various types of diagnostic equipment. Includes equipment such as logic testers, oscilloscopes, ammeters, multimeters, etc.	Involves working in a control room that may contain computer monitors, gauges, dials, etc. Includes operating a power plant, dispatching work, monitoring security systems, air traffic control, etc.	Installing equipment for various types of telecommunication systems such as wireless communication, cable television, telephone wiring, PBX equipment, satellite communications, etc.	Involves moving material from one destination to another using equipment such as hand carts, conveyor belts, or lifting devices. Bar-code scanners may be used for inventory purposes. Forklift use is classified as operating an industrial vehicle.
Computer data entry or retrieval	**Monitoring industrial machinery**	**Using telecommunications equipment/devices**	**Groundskeeping**
Involves using a computer to enter or retrieve information. Also includes related equipment such as computer scanners, printers, external disk drives, etc.	Operating miscellaneous types of fixed placement machinery typically found in production or construction settings such as boilers, turbines, compressors, presses, mixers, textile machines, etc.	Using equipment often hand-held, but sometimes desktop that aides in wireless and other types of communication. Includes equipment such as telephones, cellular phones, CB radios, walkie-talkies, intercoms, phone switchboards, etc.	Working with plants, soil, other materials, and various tools to do landscape work, gardening, cultivation, tree trimming, etc. Gasoline powered equipment such as lawn mowers, leaf blowers, and chain saws may be used.
Using an office/business machine	**Repairing and maintaining industrial machinery**	**Operating magnetic-based equipment**	**Survey/inspection/delivery work**
Operating equipment found in an office or business environment. Includes machines such as faxes, copiers, typewriters, electric staplers, audiovisual equipment (overhead projectors), etc. Does not include computers.	Repairing and maintaining fixed placement machinery such as boilers, turbines, compressors, presses, mixers, textile machines, etc.	Operating equipment that contains a large magnet such as a book deactivator in a library, deactivator/ degaussers, machines that use nuclear magnetic resonance technology, metal detector, etc.	Includes traveling to other locations to obtain or deliver information. Also includes monitoring/patrolling, meter reading, mail delivery, messenger services, building inspections/appraising.
Operating or riding in a gas/diesel motor vehicle	**Operating electric power tools**	**Welding/metal working**	**Meeting**
Involves operating or riding in a vehicle that primarily runs on streets and highways. Includes vehicles such as cars, trucks, vans, buses, and tractor trailers.	Involves operating electric motorized tools. Includes equipment such as sanders, grinders, drills, saws etc.	Using equipment to manipulate metal while doing activities such as welding, cutting, or brazing.	Includes being involved in a meeting, conference, seminar, training session, or pre/post shift debriefing.

A prototype electronic questionnaire was also developed in basic HTML code. A sample screen-print is shown below.

Figure 3-2. Sample screen print of web-based questionnaire.

3.3 QUESTIONNAIRE FIELD TESTING AND EVALUATION

The evaluation study collected personal MF exposure data from 43 subjects over an 8-week period. We obtained personal exposure data for 84% (21/25) of the tasks on the CSU task log and 66% of all tasks (21/32). Observed means for subjects are found in the Appendix. We collected spot measurement data for 56% (14/25) of the tasks on the CSU task log and 44% of all tasks (14/32). In all, 43 subjects contributed to our data set. The subjects completed the task log for one workday during a 4-day measurement period. On the final day the EMDEX was retrieved and spot measurements were collected when possible. A summary of the results for the evaluation study is presented below, and compared to results from the DOE 1000-Person Study of MF exposures in the US population (Zaffanella and Kalton 1998). Generally, the evaluation study population had a wider range of exposures than was observed on the 1000-Person Study. In comparison to typical residential exposures, the evaluation population had a higher average exposure (both mean and median) but is similar in the geometric mean to single family homes. When compared to electrical occupations, the evaluation study had a higher average exposure but a lower geometric mean. This probably arises from the fact that both management and electrical occupations are present in the evaluation study group. In comparison to all occupations in the 1000-Person Study data, the evaluation study had somewhat higher mean exposures but similar median and geometric mean values.

These comparisons suggest that the evaluation group does have substantial MF exposure above residential background, and covers a range of exposure that is at least as wide as observed in the nationwide survey. The evaluation population does have considerably higher representation (about 50%) of workers from "electrical jobs" than the general population. This should provide a better ability to estimate activities from these occupations, but could introduce some bias in to estimates for other task categories. Given the limited data set, we did not attempt to adjust the task estimates to account for sampling differences.

Table 3-1. Comparison of Evaluation Study Data to 1000-Person Study Data

Data Source	AM	SD	GM	GSD	Median	N
Evaluation study	3.28	6.61	0.61	3.05	1.4	43
*Single family home	1.08	1.73	0.65	2.66	0.6	701
*Apartments < 5 floors	1.62	1.95	1.09	2.34	1.02	143
*Electrical Occupations	2.15	1.62	1.61	2.25	--	16
*Management Occupations	1.64	2.82	0.99	2.47	--	204
*All workplaces	1.73	3.09	1.03	2.57	0.99	604

*Personal MF exposure data from DOE 1000-Person Study

3.3.1 MF Exposure Task

Results of task exposure mean estimations calculated using each method are compared in 3-2 below. Summary statistics calculated for each task using each method are shown in the Appendix.

Table 3-2. Comparison of Estimated Task Means by Method (mG)

Task	Description	1000 person	No Weight Method	Hour Weight Method	Smith Method	Robust Method
		AM	AM	AM	AM	AM
1	Three Phase linework	1.95	9.05	9.90	9.90	9.38
2	Single Phase linework	1.95	3.71	3.38	3.38	1.32
3	Nonenergized linework	1.95	3.44	2.99	2.99	2.50
4	Substation	1.95	4.70	3.82	3.82	5.01
5	Electrical and electronic equipment assembly, testing, and repair	1.95	4.58	3.53	3.53	0.34
6	Computer data entry or retrieval	1.50	1.32	1.24	1.24	.see 67
7	Using an office/business machine	1.60	4.26	4.26	4.26	.see 67
8	Operating or riding in a gas/diesel motor vehicle	1.19	1.15	1.24	1.24	0.56
9	Operating or riding in an industrial vehicle	1.14	0.43	0.45	0.45	0.54
10	Ship, airplane, train, trolley		.	.	.	.
11	Monitoring in a control room or dispatch center	0.83	8.29	6.94	6.94	0.82
12	Operating/tending industrial machinery	1.08	31.27	50.00	50.00	102.26
13	Repairing and maintaining industrial machinery	1.51	1.41	1.29	1.29	1.28
14	Operating electric power tools	1.31	.	.	.	.
15	Operating non-electric power tools	1.30	0.34	0.34	0.34	0.34
16	Installing/maintaining telecommunications networks	3.29	1.61	1.61	1.61	1.61
17	Using telecommunications equipment/devices	1.19	6.19	8.88	8.88	0.59
18	Operating biomedical/analytical equipment	2.99	.	.	.	.
19	Electric furnace or heating device		.	.	.	.
20	Operating magnetic-based equipment	0.61	.	.	.	.
21	Welding/metal working	2.38	1.60	1.60	1.60	4.20
22	Operating x-ray equipment	0.91	.	.	.	.
23	Cleaning/janitorial work	1.94	0.90	1.06	1.06	3.42
24	Cooking/food preparation	3.21	.	.	.	.
25	freight handling/warehouse work	0.80	0.44	0.41	0.41	0.62
26	Groundskeeping	1.08	.	.	.	.
27	Personal services	2.20	.	.	.	.
28	Production assembly work	1.41	.	.	.	.

Task	Description	1000 person	No Weight Method	Hour Weight Method	Smith Method	Robust Method
		AM	AM	AM	AM	AM
29	Retail check-out	1.38	.	.	.	.
30	Survey/inspection/delivery work	1.29	.	.	.	.
31	Meeting	1.30	0.72	1.00	1.00	.see 51
32	Lunch/break	.	3.13	1.94	1.94	.see 51
33	Other	.	3.03	1.04	1.04	.see 51
34	TOTAL (all tasks)	.	3.27	3.16	3.16	.
67	Task 6+7 (Computer data entry or retrieval + Using an office/business machine)	.	.	.	1.26	0.72
51	Task 31+32+33 (Meeting+Lunch/break+Other)	.	.	.	1.42	0.01

We extracted exposure data from each subject for each of the tasks on the task log from the EMDEX files using the times reported. In some cases, it was necessary to correct the times from the task log to reconcile these with the time log data (see Discussion). Using the various estimation methods described in the methods section, the task data from individual subjects was combined to obtain task-specific exposure estimates for each category. These means for each task and method appear in the Appendix along with estimates derived from the 1000-Person Study jobs.

The task specific estimates for the evaluation study typically diverge considerably compared to those estimated from the 1000-Person Study: they are particularly higher for electrical work and industrial machinery. For some categories, such as *operating an industrial vehicle*, *cleaning/janitorial work*, *freight handling*, or *operating non-electric power tools,* the task specific estimates from the evaluation study were considerably lower. The range of the task estimates was far greater in the evaluation study data, regardless of the estimation method, which probably reflects a "regression to the mean" due to the lack of detailed information that was available from the 1000-Person Study data set. The 1000 person estimates were largely derived from occupational categories, matched to certain tasks, rather than obtained directly from task logs.

In comparison, the task specific estimates are reasonably consistent across all the estimation methods used. The hour weighting and Smith methods both will give a time-weighted average (TWA) exposure value and should produce identical mean estimates. Comparing these to the no weighting method gives an indication of the importance of task duration compared to simple frequency of task reporting in the task logs. In most cases, the duration information only results in a modest change in the mean estimates, suggesting that a simplified exposure surrogate could use just frequency of tasks as a metric.

3.3.2 Comparison of Task Estimation Methods

The figure below compares the estimated task means for the robust regression method and the Smith method. In both methods for this comparison, tasks 6 (computer data entry or retrieval) and 7 (office/business machine) are combined to form task 67 and tasks 31 (meeting), 32 (lunch/break), and 33 (other) are combined to create task 51. The 95%

confidence intervals around the Smith Method means are shown. All the Robust Regression method means fall within the Smith method uncertainties. The reverse is also true (see Appendix).
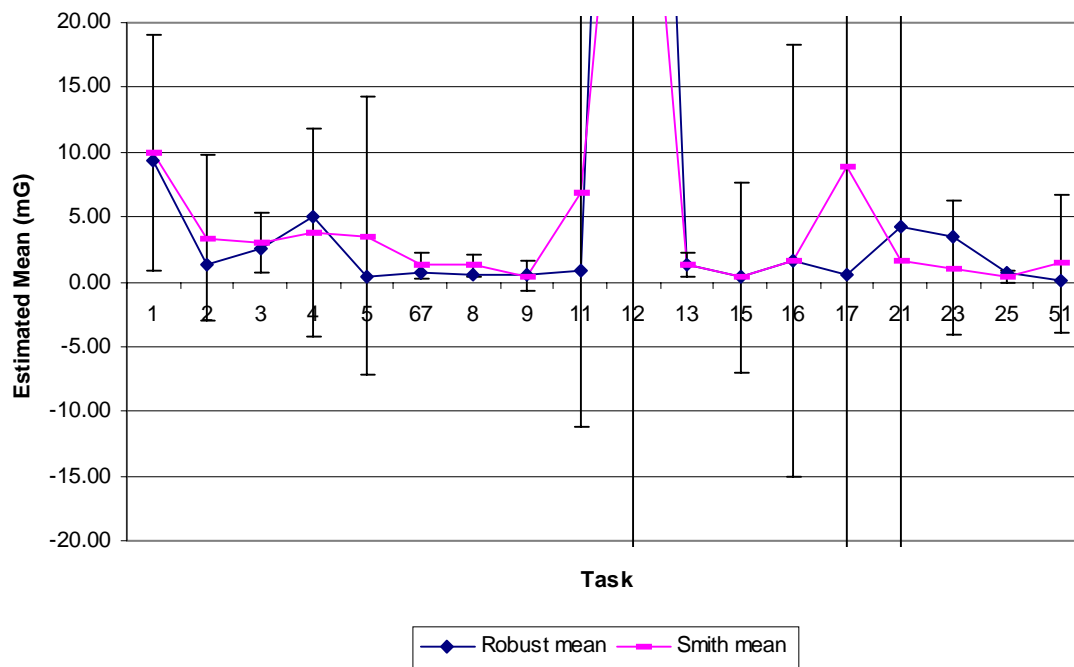

Figure 3-3. Comparison of estimated task means for the Robust Regression Method versus the Smith Method (with confidence intervals shown around the Smith data)

3.4 RE-CREATING EXPOSURE-DAY

Subject exposure estimates from each method can be found in the Appendix.

3.4.1 - Robust Regression Method

The task specific exposure estimates were applied using the task sets recorded by each subject in the task log to recreate a full-shift exposure estimate for each individual. The Smith method and the robust regression method gave the most accurate estimates of full shift exposure (see Appendix). The figure below shows the performance of the robust regression method compared to the observed mean values for subjects. The high correlation of the predicted means to the observed means shows that the task data can

provide reasonably good estimates of individual exposures. Naturally, the regression method produced a high correlation, since the task estimates were derived from the same data set. When applied to a new population, the correlation will likely be lower. One approach to account for this is to compute a jack knife estimate of the R^2 value by re-sampling the data. This approach was not feasible due to the sparse nature of the data set. One can somewhat account for the shrinkage in the R^2 value due to the large number of predictor variables by computing an adjusted R^2 value; the adjusted R^2 is 0.77 for the robust regression model, indicating reasonably good association for the model.
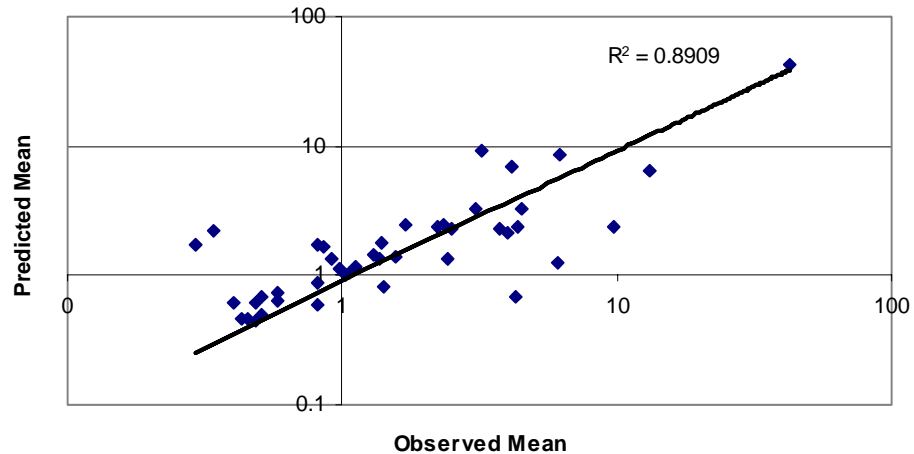
Figure 3-4. Observed mean versus mean predicted from Robust Regression Method for subjects (log-log scale)

3.4.2 Hourly Weighting Method

The hourly weighting method returns the same mean as the Smith method, but results in higher variance for each subject (see figure below). This occurs because the hourly weighting method gives greater variability for tasks, particularly for tasks with high peak exposure and short duration. In practice though, most subject estimates are unaffected in this group.
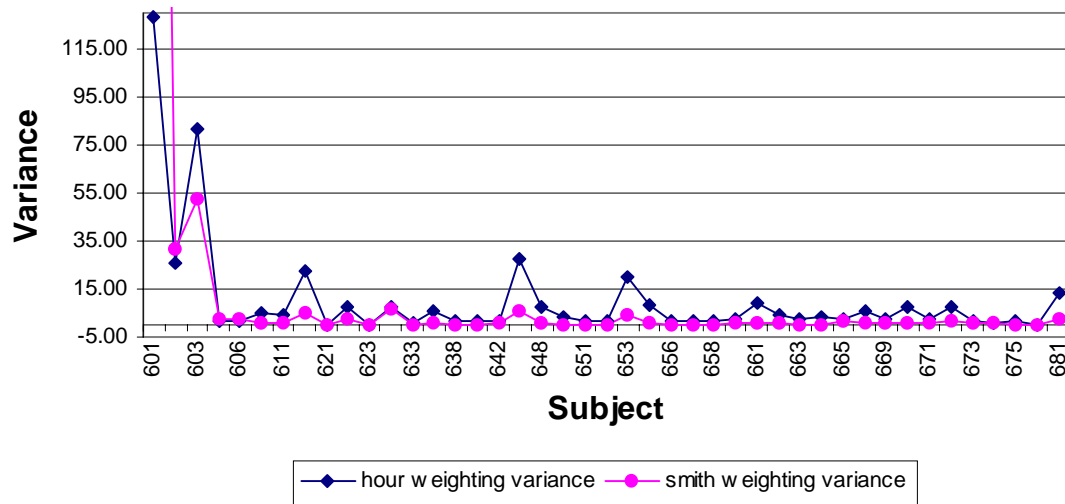
Figure 3-5. Comparison of Variance for Hour Weighting versus Smith Weighting

3.4.3 Comparison of Methods

The figure below compares the estimated subject means from the robust regression and Smith methods. As in the comparison of estimated task means, all the robust regression means fall within the 95% confidence interval around the Smith means.
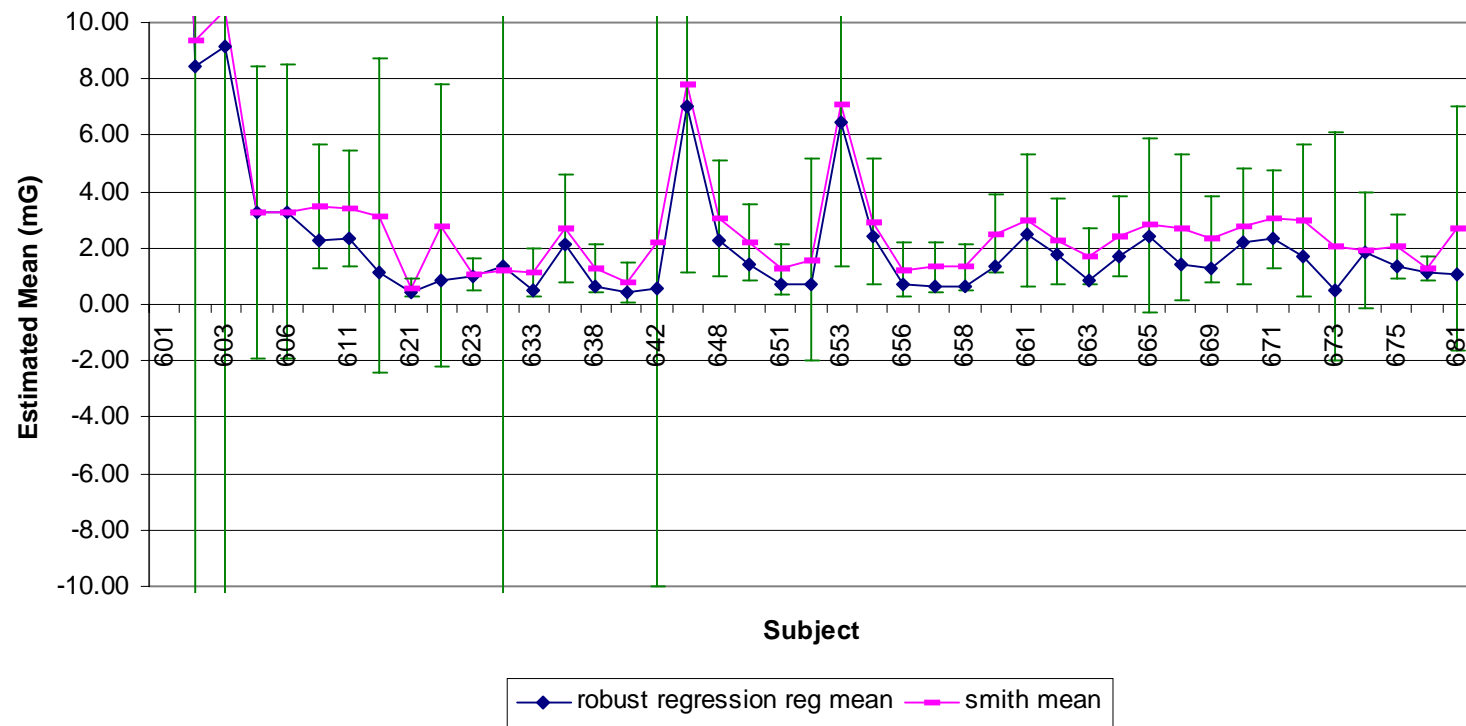
Figure 3-6. Comparison of estimated subject means generated by the Robust Regression Method versus the Smith Method with combined task categories (confidence intervals around Smith data)

The table below shows a summary comparison of the standardized differences (equation 2.11) between the measured personal MF exposure and the estimates generated from task sets. On average all methods slightly overestimate the true exposure, but the overestimation is less than 1 mG (see Appendix). The no weighting method overestimates the true exposure to a greater degree than the other two methods. Hour weighting and Smith weighting give virtually the same results (see figure). At true values close to zero, there is a larger degree of overestimation. At higher magnetic field levels, all methods seem to underestimate the true value, but this is based on only a few data points.

Table 3-3. Average Standardized Difference in Milligauss from Actual Value by Estimation Method

Deviation from True Value	No Weighting	Hour Weighting*	Smith Weighting*	Robust Regression	1000-Person Study
10th Percentile	-0.13	-0.20	-0.20	-0.23	-0.56
25th Percentile	0.06	0.001	0.001	-0.12	-0.16
50th Percentile	0.31	0.24	0.24	0.02	0.01
75th Percentile	1.23	0.91	0.91	0.16	0.51
90th Percentile	2.71	1.93	1.93	0.38	1.63
R^2	0.70	0.80	0.80	0.89	0.01
Average Difference from Actual Value	0.86	0.61	0.61	0.14	0.25
Standard Deviation	1.22	0.99	0.99	0.63	0.78

* Hour and Smith weighting differ at 5 decimal places

The figure below shows a comparison of the cumulative distribution of standardized differences generated for all subjects by the various task estimation methods. The figure shows that the robust regression method produces individual estimates with the smallest bias (relative to the median or 50 percentile) and the highest precision (smallest spread in the distribution). The other methods, the smith method and hourly weighting method, both perform about the same, and tend to predict more poorly for extremely large or small values of personal exposure.
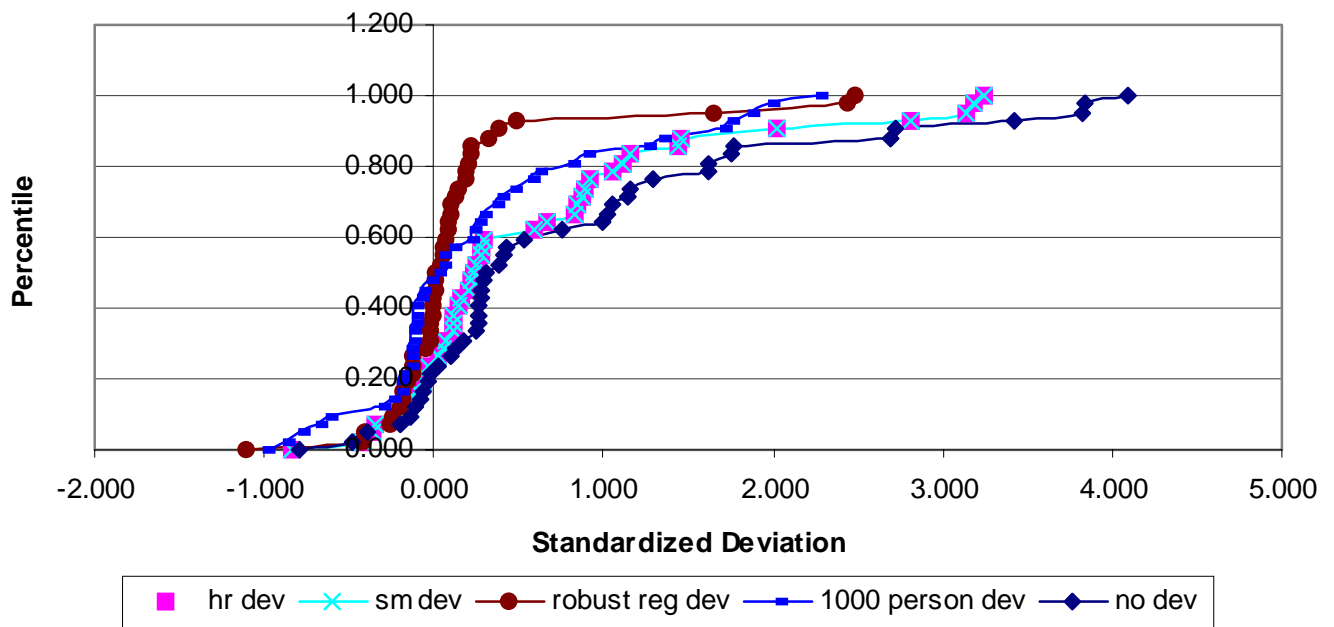

Figure 3-7. A Comparison of the Cummulative Distribution for All Methods